Spallation and Other Muon-Induced Backgrounds in the SNO Detector

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The Sudbury Neutrino Observatory is a water Čerenkov detector consisting of 1 tonne of heavy water (D_2O) surrounded by a sphere of nearly 10,000 phototubes. When a high-energy muon travels through the SNO detector, several processes can occur which can leave behind long-lived radioactive nuclei. Muons which enter SNO can be identified by the light they deposit in the optically separated light water buffer surrounding the detector. All events which occur within 20 seconds following a muon trigger are removed. Since the muon rate in SNO is roughly 70 per day [1], this cut reduces the data set by roughly 1.6%.

The first process is muon capture, where a muon stops in the detector, captures on a nucleus, and a muon neutrino is produced. An example of such a process is $\mu + {}^{16}_{8}\mathrm{O} \rightarrow {}^{16}_{7}\mathrm{N} + \nu_\mu$. By considering the stopped muon rate in SNO (roughly 1.4 per day [1]), the μ^+/μ^- ratio in [3], and using the measured fraction of 1.66% of stopped muons in ^{16}O forming bound states of ^{16}N [2], one can conclude that the ^{16}N background from this source is roughly one event inside the fiducial volume for 300 days of data.

Another process which can occur is muon-induced spallation, where a muon breaks apart a nucleus into smaller fragments, which can be radioactive. These radioactive products can be backgrounds to the Neutral-Current solar neutrino signal if they decay by the production of a neutron, or if they produce a gamma ray with an energy above 2.2 MeV, which can photodisintegrate ^{2}H. The radioactive muon followers can also form a background to the CC signal if they undergo beta decay. The spallation products from ${}^{16}_{8}$O have been extensively studied by Super-Kamiokande [4]. From their measurements the extrapolated backgrounds in the SNO detector beyond the 20 second muon follower cut are negligible. Now that 2 tonnes of NaCl have been added to the detector, we must also consider muon-induced spallation on Na and Cl. However, since Na and Cl are present in the D_2Oat the .2% level, the estimated spallation backgrounds from Na and Cl are also negligible.

The energetic muons can also disintegrate ^{2}H, producing prompt neutrons. The majority of these will capture on ^{35}Cl in the salt D_2O in roughly 5 ms and should be removed by the muon follower cut. Based on studies of the neutron production following muons [5] and comparisons of the neutron capture cross sections, we expect the backgrounds from neutron capture on ${}^{23}_{11}$Na and ${}^{37}_{17}$Cl to be less than .4 events for 300 days of data.

The fast neutron (n,α), (p,n), and (p,α) reactions following a muons are not expected to yield significant backgrounds. The (n,p) reaction on ${}^{16}_{8}$O, which produces ${}^{16}_{7}$N is of some concern due to the high decay energy and 10.3 second life-time. Studies of the time-correlation of events with muons are being performed (using work done in [6]) to measure or limit the amount of ${}^{16}_{7}$N which is produced by fast muons. This will be used to estimate how much contamination remains in the data after the 20 second muon follower cut has been applied.

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